

NASA at UC

A PUBLICATION ON NASA RESEARCH AT THE UNIVERSITY OF CALIFORNIA



Autumn, 2000

NASA and UC work together to understand the universe, planet Earth and the origins of life

UC President Richard C. Atkinson and NASA Administrator Daniel S. Goldin have signed an agreement that makes UC an integral partner in NASA Ames Research Center's new research park. "UC and NASA scientists will work together on advances in science and technology that will drive new industries and provide new products benefiting California's economy," said Atkinson.

With the presence of three major NASA research facilities in California – Pasadena's Jet Propulsion Laboratory, Mountain View's Ames Research Center, and Edwards's Dryden Flight Research Center – UC and California continue to reap the benefits of helping NASA fulfill its mission.

In FY99, NASA funded almost \$80 million of research at the Univer-

sity of California. This research explored not only other planets and stars, but also focused on our own planet.

NASA is helping UC apply satellite and high-altitude imaging to explore Earth's natural environment. NASA is also helping researchers better understand the origins of life by studying organisms living in extreme environments and by searching the universe for the conditions that led to the beginning of life on Earth.

In FY99, UC Berkeley earned \$29 million for NASA research, the most awarded to a UC campus from NASA, and 37 percent of the total awarded by NASA to UC. Over \$10 million of this amount came from a single, multiyear grant for the CHIPS (Cos-

The things NASA will do in the not-too-distant future can change the way we look at ourselves, the world and our universe.

*Daniel S. Goldin
Administrator of NASA*

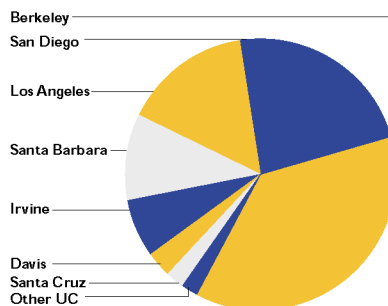
mic Hot Interstellar Plasmaspectrum-eter) mission. This satellite will monitor regions of hot plasmas in deep space in the ultraviolet portion of the spectrum.

NASA awarded over \$18 million in research funding (23 percent of UC's funding from NASA) to UC San Diego. Awards included \$6.6 million for the Triana satellite. Triana will occupy a unique orbit at the center of gravity between Earth and Sun, and will constantly monitor the sunlit face of the Earth.

UCLA was awarded \$12.2 million (15 percent of the NASA total), for a variety of different projects, from managing Internet traffic to exploring countermeasures to muscle atrophy in zero-gravity. UC Santa Barbara earned over \$8 million (10 percent) with projects that emphasized the study of Earth's environment. The campuses at Irvine, Davis and Santa Cruz earned \$5.4 million, \$2.5 million, and \$1.7 million respectively.

- In FY99, NASA funded almost \$80 million of research at the University of California.
- NASA funded research at all nine UC campuses and the Lawrence Livermore National Laboratory.
- NASA and UC have just signed an agreement to become partners at NASA Ames Research Center's new research park in Mountain View, CA.
- UC Davis professor Susan Ustin is a leader in the field of remote sensing – using satellite and other high-altitude multispectral cameras to study Earth's environment (see pp. 4-5).
- UCLA astronomer Eric Becklin is the chief scientist for the SOFIA infrared telescope, which will be based at NASA Ames (see p. 3).

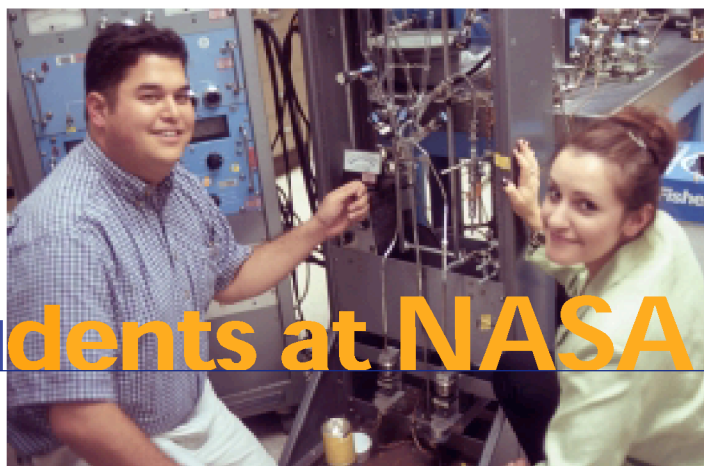
**NASA Research Funding by Campus
FY99**



source: UCOP grants database

- At UC Santa Cruz, Dale Stansbury, dean of Extension Education, has helped craft an innovative program to bring student interns to NASA Ames (see p. 2).

Students at NASA Ames



UC Santa Cruz student Mike Kubo demonstrates this Nuclide Mass Spectrometer to Victoria Kushnir, UC Berkeley graduate.

In 1998, Dale Stansbury, dean of UC Santa Cruz Extension, saw two problems and helped NASA craft a single solution to both. NASA Ames Research Center was having trouble recruiting workers in Silicon Valley's tight labor market. Meanwhile, students at UC Santa Cruz and other UC campuses clamored for real-world work experience to complement their classroom learning.

The solution to both these problems was the Education Associates program, where students can earn academic credit and income by working on projects with NASA Ames researchers.

NASA Ames is located at the foot of the San Francisco Bay near Mountain View, CA, and operates the runways at the former Moffet Field Naval Air Station. Ames was originally founded in 1939 as a federal aircraft research laboratory and in 1958 became part of NASA.

Ames leads the agency's research in several areas, including information technology, rotorcraft and wind tunnel testing, and astrobiology – the search for life in the universe and the conditions that support it.

The Education Associates program was launched at NASA Ames in May of 1998. NASA project managers develop positions, provide funding and select associates.

Education associates are expected to complete a project assignment, submit a written report at the end of the assignment and participate in seminars and other educational activities at NASA Ames. In addition, they make project presentations at their educational institutions and to public organizations.

University faculty and students from the undergraduate to the post-doctoral levels are eligible to become associates. The program operates year-round and appointments may extend from two months to one year.

Although the program takes students from across the United States, the majority of students come from one of the UC campuses. Mike Kubo, 24, is a UC Santa Cruz

senior and a NASA education associate. Working in the laboratory of NASA researcher Dave Des Marais, Kubo

conducts experiments on carbon samples from bacteria and other microbes that have died and been deposited in layers in hypersaline and hydrothermal environments.

By tracing the amounts of various isotopes of carbon, the life processes of the microbes can be determined. The ultimate goal is to develop a technique for identifying ancient terrestrial and possibly extraterrestrial microbial life.

Victoria Kushnir is a recent UC Berkeley graduate now enrolled in a Master of Public Administration program at San Jose State. She has worked for over a year in the NASA Ames public affairs office, producing press releases and coordinating video and other conferences.

In the program's first year of operation, 65 students worked with NASA, and the number grew to 100 new students in the second year. There have been 88 different research sponsors on the NASA side. Students have come from 48 colleges and universities, and about 40 percent are women.

In addition to earning academic credit, students are paid from \$1,500 to \$2,100 per month for working in the program full time. The students have received over \$1.3 million in training awards, and NASA Ames has captured over 100,000 hours of student and faculty support. At least eight of the students have secured permanent positions at Ames as a result of the program.

Says Kubo, "My degree at Santa Cruz is in chemistry and I would like to go to graduate school in chemistry. But without research experience, getting into grad school can be tough. This internship will really boost my chance of getting accepted."

"NASA does some incredible things both for space exploration and for improving people's lives here on Earth," adds Kushnir, "and I've learned a lot about public outreach in helping get the word out."

SOFIA Takes-off



Astronomer Eric Becklin points to where the infrared telescope will be housed in a model of SOFIA. Becklin, a professor at UCLA, is the chief scientist for the SOFIA project.

To our eyes the night sky is mostly empty space, filled with occasional pinpricks of starlight. If we could see the universe in infrared light, our perception of it would change in an instant. In the infrared we could see the nurseries of the universe – vast regions of space filled with glowing dust and gas, interstellar matter that eventually will coalesce to form new planets and stars.

Humans can sense only a very small portion of the electromagnetic spectrum – that visible light portion between radio waves and infrared at lower frequencies, and ultraviolet and X-rays at higher frequencies. Early telescopes extended our ability to see visible light. Modern telescopes extend our abilities to see in other portions of the electromagnetic spectrum.

To see the universe in the infrared, a telescope must get above the infrared-absorbing water vapor in the Earth's atmosphere. Even perched on mountain tops, terrestrial (earth-based) telescopes are too low in altitude. The Hubble space telescope – a telescope mounted in a satellite floating above Earth's

atmosphere – is too far away, too expensive to reach and not designed specifically for infrared astronomy.

Researchers need a large telescope dedicated to infrared astronomy operating at an altitude of about 41,000 feet, more than two miles higher than Mt. Everest and above 99 percent of the atmosphere's infrared-absorbing water vapor. The only cost-effective way to accomplish this is to mount the telescope in an aircraft and fly it there.

Starting in early 2003, SOFIA (Stratospheric Observatory for Infrared Astronomy) will begin flying several nights each week from its home base at NASA Ames Research Center. SOFIA is built upon a modified Boeing 747 SP, the short-bodied freight version of the 747. The plane has been altered to hold a telescope with a mirror 2.5 meters (eight feet) in diameter.

The telescope assembly resembles a giant barbell with 40,000 pounds of counterweights and instruments on the front end and the telescope on the other end. A hollow shaft passes through the center of a pressurized bulkhead and floats there on a hydraulic bearing, while the telescope itself is mounted beneath a sliding door that opens once SOFIA is at altitude.

The telescope will operate at the outside air temperature of minus 40 degrees Centigrade while the researchers work in the comfort of the heated, pressurized cabin. The light from the telescope will pass through the center of the

(continued on p. 8)



SOFIA, a 747 SP, undergoing modification in Waco, TX. In front is a full scale mock-up showing the location of the telescope itself.

Remote sensing comes of age

Remote sensing – the ability to map the Earth's characteristics from aircraft and satellites – has been the beneficiary of the end of the Cold War. The advanced digital cameras and other technologies developed for spy satellites are now available for research and commercial purposes.

Two other technological advances have allowed remote sensing to blossom. Global positioning satellites (GPS) make it easier to link aerial images to ground-based field work. Geographic information systems (GIS) help keep track of the observations from both the ground and the air.

At UC Davis, professor Susan Ustin is a leader among researchers applying remote sensing to problems in agriculture, land management and other environmental issues. Ustin is a faculty member in the department of land, air, and water resources and heads the Center for Spatial Technologies and Remote Sensing.

Ustin has worked with NASA on many projects and currently is working on five projects with the agency. One of them is a joint demonstration with NASA and the Department of the Interior to determine the health of rangeland in national parks.

Flying at 60,000 feet, an ER-2 – a modernized version of the U-2, the infamous Cold War spy plane – flew over North Dakota's Theodore Roosevelt National Park. Using a camera that could take digital images in several different wave-lengths of visible and



UC Davis Professor Susan Ustin describes hyperspectral images and what they reveal about farmland.

infrared light, Ustin determined the extent of damage to rangeland due to invasion by a toxic weed called *leafy spurge*. The aerial observations were later confirmed by field work in the park.

The multispectral cameras of the past are now being replaced with hyperspectral cameras. Instead of recording images in a few narrow frequency bands, hyperspectral cameras can record images in hundreds of distinct frequencies of visible light and infrared. These cameras can record the entire spectrum of light

being emitted or reflected from a spot of land, in not only all the visible colors but in the infrared as well.

Ustin has put these cameras to use in distinguishing between various plant species, especially between native plants and invasive species. "California is now under an onslaught from a second wave of invasive plant species," she explains. The first wave of invaders were the annual grasses that were carried to California in the coats of sheep and cattle in the 1800s. It is these annual species that turn golden each summer – the native grasses were perennials and stayed green much longer.

The second wave of invaders includes such plants as *pampas grass*, *ice plant* and *yellow star thistle*. Because most higher plants share a similar metabolic chemistry based on photosynthesis, it can be difficult to tell them apart from the air, but by using hyperspectral cameras and timing the images during critical phases of the growing season, Ustin is learning to distinguish and monitor the spread of invasive species.

A second project with NASA involves the development of an unpiloted aircraft that would be used for remote sensing of agriculture at altitudes below 10,000 feet. "As land and water become more expensive in the U. S., farmers have to farm smarter in order to stay competitive in world markets," says Ustin. Remote sensing can help by monitoring the water absorption of crops in different fields, helping to determine the optimal rate of irrigation. Much of California's Central Valley lies above a layer of

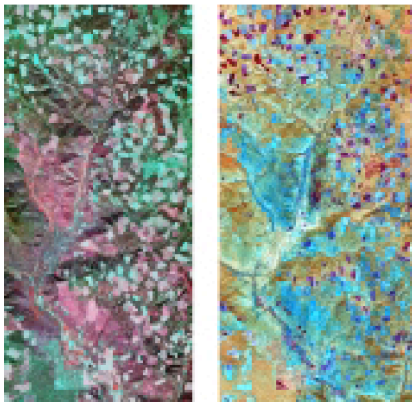


An unpiloted airplane and its digital camera.

clay. Depending upon how close this clay layer is to the surface, different fields might absorb more or less water. While underwatering can cause crops to wither, overwatering not only wastes water, but tends to leech salt from subsurface layers, which can also damage crops.

Visible light wavelengths span the electromagnetic spectrum from violet at 400 nanometers to red at 700 nanometers (a nanometer is one-billionth of a meter). Near-infrared wavelengths run from 700 to 2500 nanometers. In plants, major water absorption bands occur at wavelengths of 1180, 1450, and 1940 nanometers. By using hyperspectral cameras, researchers can evaluate the level of hydration of crops, and help farmers water selectively only as necessary.

Recording digital images on a high-capacity hard drive, soon

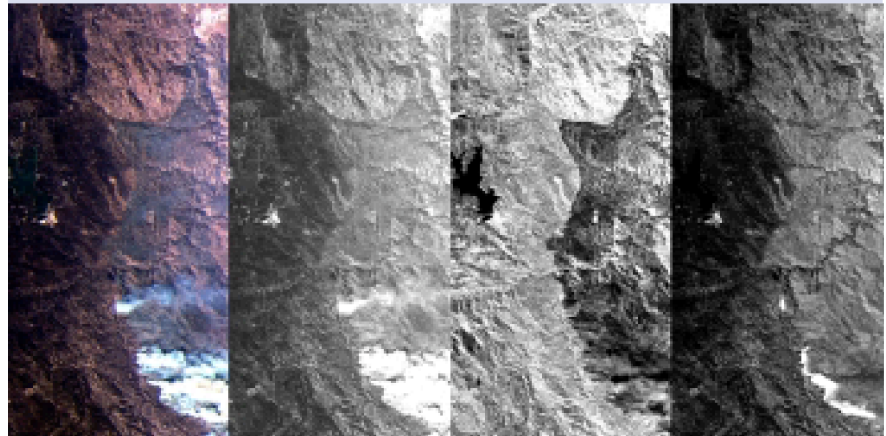


These false-color images reveal how a forest in Washington State is recovering after clear-cutting.

unpiloted planes will be able to fly over a farming region and record immense amounts of information in a cost-effective manner. These data can be made available to farmers over the Internet.

“We’ve just scratched the surface of what remote sensing can tell us about Earth’s environment, says Ustin.” NASA and UC will continue to collaborate on developing this important technology.

A forest fire in four different wavelengths



full color

500 nm (green)

1000 nm (infrared)

2000 nm (infrared)

Remote sensing has a tremendous number of applications in monitoring the environment, from measuring rain forest depletion, to monitoring snow pack levels in watersheds, to monitoring crops for pest damage and optimal irrigation, and to assessing the changes in vegetation due to global warming. The examples above show how multispectral images reveal important information about a forest fire.

The four images above were taken at the same time and show a forest fire near Willows, CA, in 1999. The first image on the left is in full color. This image records what the human eye sees. Smoke is visible in the lower right hand corner, but the extent of the fire is hard to see.

The second image is taken at 500 nanometers, the green portion of the visible spectrum. This is similar to what a camera equipped with a green filter would take using black-and-white film. The image shows details similar to the color image. Again, smoke is visible in the lower right, but the burned area does not stand out.

The third image is shot at 1000 nanometers, in the near-infrared part of the spectrum. In this image two important objects stand out: on the left margin a reservoir is now visible, and on the right the extent of the burned area is obvious.

The final image was shot at 2000 nanometers, well into the infrared portion of the spectrum. First, the smoke is now invisible – infrared light of this wavelength is not absorbed by smoke, haze and other particulates in the atmosphere. However, the flame front stands out clearly in this image, separating the area where the fire is still burning from the area where the fire has burned out.

Images such as these can be of immense help in fighting fires, helping to pinpoint the precise areas that need to be doused from the air, or finding safe zones for smoke jumpers.

BUILDING BETTER turbine blades

As direct flights between distant cities become more common, reliable fuel-efficient engines will become more imperative. Working on a NASA grant, professor John Kosmatka of the UC San Diego structural engineering department is designing better composite turbine blades for passenger jet engines.

Australia's Qantas Airlines currently flies direct between Sydney and Los Angeles, a journey of 7,500 miles. A direct Singapore-New York route would fly close to the North Pole on its 9,500 mile journey and may become reality in a few years due to advances in airframe and engine design.

The new long-range Boeing 777-200 will be able to fly over 10,000 miles (8,860 nautical miles) nonstop and keep 300 passengers aloft for 18 hours. This 777 will be powered by two General Electric GE-90 engines. Within a few years this engine will be available with composite turbine blades.

A jet engine has turbine blades in front to compress the air flowing through the engine, and another set in the back in the exhaust stream to drive the compressor blades up front. While a fighter jet engine depends upon the stream of hot exhaust gases to produce thrust, in a passenger jet turbofan engine, the first stage compressor blades are actually much larger than the engine itself, and the blast of air produced by the blades generates the majority of the thrust.

Almost all current jet engines use metal turbine blades. The blades deeper in the engine must be made of metal to withstand high temperatures, but this is not the case for the first compressor stage in an engine like the GE-90, where the blades are about four feet long. If a metal turbine blade breaks in the compressor, it can start a cascade of broken blades ripping through the engine, often causing catastrophic engine failure. Because of the risk of blade breakage,

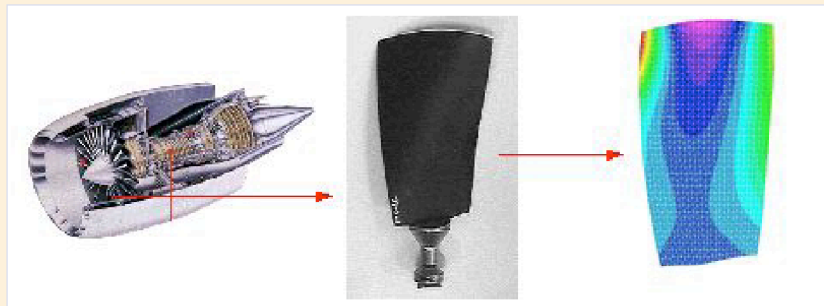


Diagram shows modern turbofan aircraft engine, one blade from the turbine, and a computer simulation of stress on the blade.

engines must be inspected frequently, adding to downtime and increased maintenance costs.

"Metals may not be the best material for jet turbine blades," says Kosmatka. "The damping characteristics of metals are poor, and the vibrations within a jet engine lead to harmonic stress on the blades, not unlike how certain loud, high-pitched sounds can shatter a wine glass."

Professor Kosmatka is experimenting with blades that incorporate viscoelastic damping materials within their laminate skins. The goal is to produce a blade with damping characteristics strong enough to virtually eliminate vibrational stresses, greatly increasing the life of the blades.

Composite blades in aviation are not farfetched. Wood is the first composite material, and laminated wooden propellers were used for decades.

Most helicopters use composite blades, not only because of performance and weight, but because they are much more cost-effective. Although composite helicopter rotors are more expensive to buy, their lower maintenance cost over the life of the

rotor makes them cheaper over time.

For passenger aircraft, composite fan blades have another advantage – in the event of blade breakage, the composite blade will disintegrate as it gets sucked into the engine, causing little damage. And more flexible blades are more likely to withstand direct hits from birds or other flying objects.

According to Kosmatka, "As an engineer, I'd like to be able to say that composites will lead to huge performance increases, but what we are really after is better reliability." For passengers who will be in the air for 18-hour stretches, increased reliability is worth the effort.

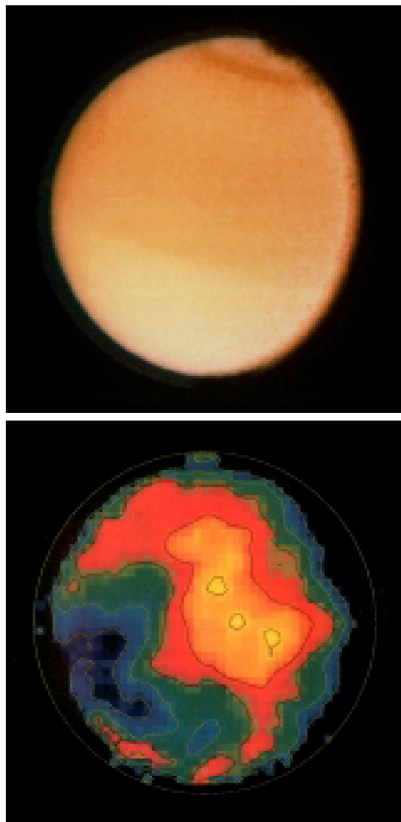
What lies under the clouds of Titan?

Titan, the largest of Saturn's 18 moons, remains an enigma. Shrouded by a thick nitrogen, methane and hydrocarbon atmosphere, glowing a dull orange through telescopes, little is known about what lies on its surface. With help from NASA and the new technology of adaptive optics, UC Berkeley planetary scientist Imke de Pater and graduate student Henry Roe are probing beneath Titan's cloud cover. Assisting them are collaborators Seran Goddard, Bruce Macintosh, and Claire Max of the Lawrence Livermore (CA.) National Laboratory.

Of the almost 70 planetary moons in the solar system, two especially intrigue astronomers because of the possibility they might harbor life, or at least the conditions for life. Europa is one of the 16 moons of Jupiter, and is now thought to contain an ocean of liquid water concealed under a thick layer of ice. Titan, with a diameter 50 percent greater than the Earth's moon, is one of the largest moons in the solar system and the only one with a dense atmosphere.

Astronomer Carl Sagan noted Titan's resemblance to a very young Earth, Earth before eons of plant evolution and photosynthesis increased the oxygen content of our planet's atmosphere. Although Titan is much colder than Earth, with an average temperature about 200 degrees below zero Centigrade, it has an atmosphere composed primarily of nitrogen. We have found life on Earth in regions very unexpected – deep on the ocean floor, in Antarctica and even hundreds of feet below the Earth's surface. The name given to bacteria and other simple life forms living in these hellish conditions is "extremophiles." Might extremophiles survive on Titan?

Working with Chris McKay of NASA Ames Research Center, de Pater, Roe and LLNL colleagues have used the UC-operated Keck telescopes on Hawaii's Mauna Kea volcano to glimpse at Titan's surface. Even at 14,000 feet, the Keck telescopes must see through the distorting layer of Earth's atmosphere, lowering their ability to resolve distant objects in space.



In visible light (top), details of Titan's surface are obscured by its dense atmosphere. In the digitally-enhanced false color image (bottom), the low lying areas (possibly oceans of liquid hydrocarbons) appear in blue and black, while higher areas (possibly mountains of rock and water-ice) appear in yellow and orange.

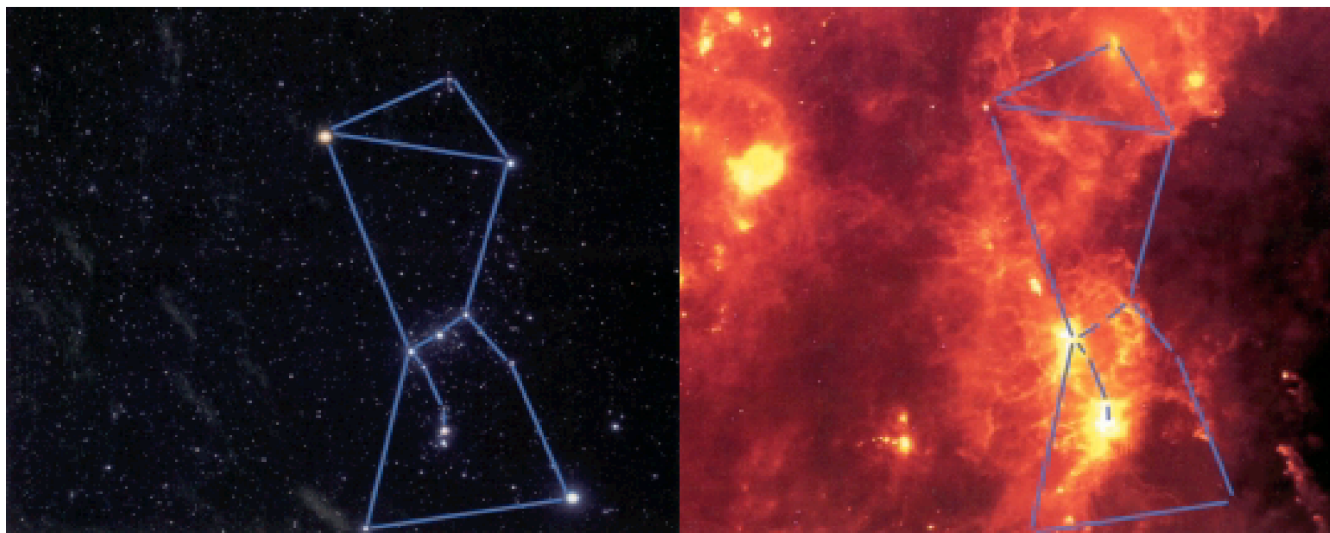
Adaptive optics cancel these atmospheric distortions. Pioneered at Lawrence Livermore National Laboratory, adaptive optics employ a small, flexible, computer-controlled mirror placed in the light beam bouncing off a telescope's main mirror. Using the light from a "guide star" – a bright object in space, or even a laser beam shot into the sky – the computer samples the wavering image of the guide star and sends signals to the smaller mirror, inducing slight distortions in its surface that undo the rippling distortion of the Earth's atmosphere. Using adaptive optics, terrestrial telescopes can rival the images produced by the Hubble space telescope.

Adaptive optics have allowed de Pater to observe Titan in very narrow frequency bands in the infrared, frequencies at which the smoggy atmosphere of Titan is transparent. De Pater and colleagues have caught a glimpse of a world right out of science fiction. Along with other planetary scientists they speculate that Titan's skies rain hydrocarbons, possibly forming oceans amidst mountains of rock and water-ice.

Can Titan harbor life? Or at least the conditions that would allow life to emerge, so-called prebiotic conditions? Possibly. De Pater cautions against jumping to conclusions: "We don't know enough yet about Titan to speculate about whether life exists there. For now we are concentrating on learning more about the composition of the land masses, oceans and atmosphere." But even if life is never discovered there, studying Titan will give us insights into the distant past of our own planet, and how the conditions that support life arose here on Earth.



Professor Imke de Pater



On the left, the constellation Orion in visible light. On the right, the same constellation in infrared light, which reveals interstellar clouds of gas and dust. Images courtesy of NASA/Cal Tech Jet Propulsion Laboratory.

(continued from p. 3)

hollow shaft to the front side of the bulkhead, where instruments will record the data.

A system of computer-controlled gyros and actuators will minimize vibrations, allowing SOFIA to resolve objects as small as 1 arcsecond, or 1/3600 of one degree. By comparison, a quarter held at arm's length occupies about 2.5 degrees of arc and will easily obscure the moon, which fills about one-half a degree of arc. If you moved that same quarter over 3.2 miles away, it would occupy only one arcsecond. SOFIA could still detect the quarter and analyze any infrared energy it emits.

SOFIA is not only innovative from an engineering standpoint, its administrative structure is also uniquely streamlined. NASA has contracted for the development and operation of SOFIA to the Universities Space Research Association (USRA), a private, nonprofit consortium of universities incorporated under the auspices of the National Academy of Sciences in 1969.

USRA will operate SOFIA in conjunction with the German Aerospace Center, which is responsible for building the telescope itself. United Airlines will main-

tain the aircraft at its facilities in San Francisco and Oakland, and will provide the pilots to fly SOFIA.

The chief scientist on the project is UCLA professor Eric Becklin. Becklin was also a principal investigator for the Kuiper Astronomical Observatory, an earlier, smaller (and much more cramped) 0.9 meter flying telescope.

Several other UC campuses will play a role in developing and operating SOFIA and its instruments. Ian McLean at UCLA is building the test camera for the telescope. Reinhard Genzel at UC Berkeley is working on advanced infrared detectors, and researchers from UC Santa Cruz will assist with recoating the 2.5 meter mirror every year.

During the summer months in the northern hemisphere, SOFIA will be based in New Zealand to take advantage of the longer winter nights there and to observe objects visible only from southern latitudes.

Says Becklin, "We can hardly wait to begin flying and making discoveries with SOFIA. This telescope will give us the ability to answer a number of fundamental questions, such as how stars and planets form and whether life started in space."

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